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OVERVIEW OF ADVANCED SYSTEMS DIVISION CRITERION RESEARCH (MAINT--ETC(U)

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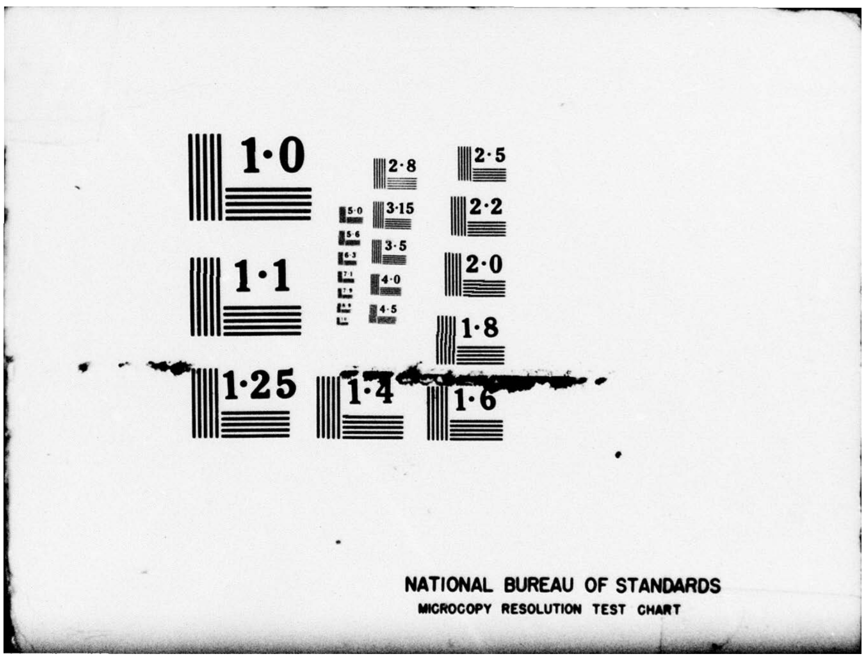

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AIR FORCE HUMAN RESOURCES LABORATORY

OVERVIEW OF ADVANCED SYSTEMS DIVISION CRITERION RESEARCH (MAINTENANCE)

By

John P. Foley, Jr.

ADVANCED SYSTEMS DIVISION
Wright-Patterson Air Force Base, Ohio 45433

December 1977

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AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235

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This report was submitted by Advanced Systems Division, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio 45433, under project 1710, with HQ Air Force Human Resources Laboratory (AFSC), Brooks Air Force Base, Texas 78235.

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life cycle costs	measurement and evaluation vocational education

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

See Over

A prime but seldom considered cause of the current high maintenance cost of DOD hardware, and thus the high ownership cost of systems, is the current criteria used by personnel systems to select, train, assign, and promote maintenance personnel. The current criteria emphasize the ability to obtain high scores on paper-and-pencil theory and job knowledge tests. This paper summarizes the many studies which indicate that such tests have little demonstrated relationship to ability to perform job tasks. This current testing emphasis must be shifted to the demonstration of the ability to perform job tasks. Such a shift is also a necessary factor for the implementation of improved job instructions and job (task) oriented training technologies. Such technologies have great potential for reducing high maintenance costs.

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personnel selection
psychology individual and group
system effectiveness measures
symbolic substitute job tests
video testing

Item 20 (Continued)

The criterion research program of the Advanced Systems Division (AS), described in this paper, has included important aspects of the criterion problem as it applies to the measurement of ~~such~~ a ability to perform maintenance tasks in training and on the job. The objective of AS in the solution of this problem is to get as close to the real job as possible. When "on-line" tasks occur often enough, their structured observation may be appropriate. *But* when such observations are not appropriate or when tasks occur infrequently, we propose to have the tasks performed "off-line" in a job-like environment. The Advanced Systems Division approach to the development of such measures was started with an analysis of the structure of the man/hardware interface for maintenance. Based on the results of this analysis, a model test battery of job task performance tests (JTPT) was developed for electronic maintenance. Using this model as the criterion, batteries of graphic and video symbolic substitute tests were also developed. Several of the graphic symbolics have indicated respectable empirical validities but require more refinement and tryout. The attempts to develop video symbolics were unsuccessful.

A continuing research program based on what already has been accomplished is recommended. This includes the development of a model battery of JTPT together with symbolic substitutes for maintenance tasks generated by a typical mechanical hardware. The perennial problem of getting new technologies such as JTPT implemented is also briefly discussed. There is definitely a requirement for a structured mechanism which will guarantee the orderly institutionalization of such technologies as well as their integrity.

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PREFACE

This report represents a portion of the exploratory development program of the Advanced Systems Division, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio.

This paper was presented at a tri-service symposium on Criterion Development for Military Jobs, San Antonio, Texas, 23–24 June 1977.

The preparation of this report was documented under task 171010, Evaluating the performance of Air Force Operators and Technicians of project 1710, Training for Advanced Air Force Systems. The effort represented by this volume was identified as work unit 17101007. Dr. Ross L. Morgan was the task and project scientist.

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I. INTRODUCTION

The Advanced Systems Division (AS) of Air Force Human Resources Laboratory (AFHRL) has had two separate and distinct criterion R&D programs--one concerning pilot performance, and the other concerning maintenance performance. Today I am addressing our maintenance program.

Maintenance of hardware is currently an extremely costly operation for the Department of Defense (DOD). High maintenance cost is the primary cause of high systems ownership cost. For some electronic maintenance specialities, nearly one year of broad formal training is given first enlistment personnel. And maintenance training generally is long and costly. Even with such lengthy training, the efficiency of maintenance could be greatly improved. Improved job instructions and information, as well as increased use of job (task) oriented training have great potential for decreasing maintenance training time and improving the job performance of maintenance tasks.

But, to maximize such potential and to ensure more efficient maintenance, the criteria for the selection, training, assignment, and promotion of maintenance men should be the demonstrated ability of maintenance personnel to perform the tasks of their jobs. To enforce such criteria, the key job tasks must be identified and the ability to perform identified tasks must be ascertained. Since the ability to perform many or most of the identified tasks will not be part of the normal repertoire of those being selected for jobs, appropriate action must be taken to develop the ability to perform job tasks. Of course, these actions are "easier said than done."

II. THE CRITERION PROBLEM

If we can produce a measuring device that actually measures the ability to perform the desired behaviors under all the desired conditions, we have an ultimate criterion measure. But the fact, that we usually cannot develop such a device, forces us to settle for a secondary criterion measure which is, at best, somewhat different than the ultimate. As we see it, this difference between the real world and the simulation of the real world (for testing purposes) is the criterion problem.

A common example of such a criterion problem presents itself when we attempt to measure an individual's ability to drive automobiles. To measure such ability completely we would have to devise a test that would measure his ability to perform all driving tasks of all automobiles, on all types of roads, in all traffic conditions, under all types of weather conditions, whether he is being observed or not. It is obvious that it would be virtually impossible to meet all of these conditions under practical testing conditions. We, therefore, settle for a less rigorous test criterion. We assume that he can drive any automobile adequately, if he demonstrates in a performance test that he can perform most driving tasks in one automobile, in normal traffic, while being observed.

But many times, it is inconvenient and considered too costly to administer even such a driver performance test and an attempt is made to develop a paper-and-pencil test which will determine that an individual can drive adequately. But such a test cannot be considered to be a valid substitute, unless a high empirical relationship to the criterion measure can be demonstrated. In the practical world of test development, the driver performance test would be considered an adequate, near ultimate criterion test for validation of such a paper-and-pencil substitute. Many times such a paper-and-pencil test is used without being validated against such a near ultimate criterion test. The use of such an unvalidated test would be an extremely dangerous practice, since it is assumed by most users that it measures an individual's ability to drive, when in fact, we are not sure what it is measuring.

This criterion problem has long plagued measurement theorists and practitioners, as well as curriculum researchers. The use of job tasks, and performance examinations based on these tasks as near ultimate criteria for evaluation of selection devices, was first emphasized as a result of the work of Army and Navy measurement psychologists during World War II. In 1946, Jenkins discussed the problem in light of the experiences of Navy psychologists in an article in the American Psychologist, entitled "Validity for What?"

> Psychologists in general tended to accept the tacit assumption that criteria were either given of God or just to be found lying about. . . . The novice of 1940, searching through many textbooks and much journal literature would have been led to conclude that expendiency dictated the choice of criteria and that the convenient availability of a criterion was more important than its adequacy.

In 1964, the late Rains Wallace presented a paper at the annual convention of American Psychological Association (APA), which also appeared in the American Psychologist (Wallace, 1965a). It indicated that much of what Jenkins said in 1946 was still true.

> In the 18 years which have followed, we have become wiser and sadder about the criterion problem. If we have not accomplished a great deal, if we tend to use the expedient criterion with the comforting thought that some day we will get down to constructing better ones, if we concentrate on criteria that are predictable rather than appropriate, we do operate with varying levels of guilt feelings. We have not done much about it, but we know we should.

In 1965, Wallace presented another paper, in which he addressed the criterion problem very succinctly as it applies to electronic maintenance.

> All of this is prelude to my main thesis which is in no sense revolutionary, original, or controversial. I state it because it is honored in the breach. It is that the nature of our proficiency measures determines how we select, classify, train, maintain and assess our human resources. If the measures are largely irrelevant to the jobs we want done, we will select the wrong men, classify them incorrectly, and train them wrong. This is true because these proficiency measures are, or should be, the criteria against which we validate our selection and classification procedures and evaluate our training content and methodology or our supervisory techniques. Thus, if I use a test of advanced electronics theory as the proficiency measure for electronics maintenance and as the criterion against which to evaluate a test for selecting men to go into maintenance training, I will end up choosing a selection test which rejects men who are not well above average in both reading and arithmetic ability. In the process I might reject a great many who are outstanding in their ability to get their hands on a piece of machinery and make it work. I might also accept a number who (like myself) are so lacking in the simplest manipulative ability that their hands could have been cut off at the wrists at birth without seriously affecting their outputs. So, when I decided what proficiency measures to use, I also decided what kind of men I was going to put into training for the job.
>
> But it doesn't end there. For when I now approach the problem of how to train men to perform the tasks involved in the job, I must make decisions about what should be taught and what methods should be used in teaching it. The only way I have of reaching such decisions (except by divination which is, admittedly, not a rare procedure) is to measure and compare the performances achieved with various curricula and methodologies. So, in the case of the electronics maintenance course, I put in lots of reading about electronics theory and I produce graduates who can read and write electronics theory while their equipment deteriorates in hopeless inoperativeness (Wallace, 1965b, p.4).

Influenced in part by the above statement, we at the Advanced Systems Division decided to do something about the criterion problem as it applied to maintenance. *And* although our work was at times delayed and sidetracked, twelve years later we do have some R&D completed which we can talk about. However, the grim and vivid picture that Rains Wallace painted in 1965 is still true for most of the operational Air Force.

Our approach to the criterion problem has been to study and analyze both measurement literature and maintenance jobs, and to develop job task performance tests (JTPT) for key maintenance tasks which were selected on the basis of these analyses. We developed these JTPT to be as near to ultimate job criteria as possible in keeping with the following suggestion of Frederiksen:

> The objective, presumably, is to get as close as is feasible to the ultimate criterion; but as has just been seen, when one gets too close to the real-life situation, control of the conditions for adequate observation is lost. Observation of real-life behavior is ordinarily not a suitable technique for measurement. The type of measure that is recommended for first consideration in a training evaluation study is the type which most closely approximates the real-life situation, that which, in this chapter, has been called eliciting lifelike behavior. If it is not feasible to wait for the behavior to happen in real life, then lifelike occasions can be provided for the behavior to occur in a test situation (Frederiksen, 1962, p.334).

Admittedly, an examination made up of tasks removed from their actual job environment is not an ultimate criterion test. Under actual job situations, the graduate may have to perform these tasks in cramped quarters; under stresses of time, noise, heat, or cold; or with an excited boss interfering. These conditions of stress are usually not constant variables, but change from day-to-day and from hour-to-hour. The assumption usually has to be made that the individual can perform a task under conditions of stress, provided he can perform the same task *well* under normal conditions. A formal performance examination has its own set of stresses, which may not be the same as job stresses, but their presence may tend to offset the lack of job stresses. Formal, job task performance examinations are the closest usable simulation of the real maintenance jobs presently available. They are far better than no performance tests at all.

III. REVIEW OF PERFORMANCE MEASUREMENT (PM) LITERATURE

In regard to the literature reviews and analyses made for PM (Foley, 1967, 1974), many valuable PM efforts have been reported by the Army, Navy, and Air Force. However, most of these efforts have not been *systematic* efforts, having as their prime objective the improvement of the state-of-the-art of PM. Rather, they have been *ad hoc* PM developments to support job oriented training research programs. A notable exception was the work of the Air Force Personnel and Training Research Center (AFPTRC) Maintenance Laboratory. (Another more recent systematic Army effort, accomplished by the Human Resources Research Organization (HumRRO) was not covered in these reviews (Vineberg et al., 1970a, 1970b; Vineberg & Taylor, 1972a, 1972b). As to civilian R&D, during the initial PM literature review (Foley, 1967), a serious attempt was made to identify and include the results of PM R&D from the civilian vocational education establishment. None was found.

A substantial outcome of the review of other PM efforts was a consolidation of research results concerning the correlations between results of PM for various maintenance tasks *and* paper-and-pencil theory tests, job knowledge tests, and school marks. As to their value for measuring ability to perform maintenance tasks, this research evidence gives a low rating to all of these paper-and-pencil based measures of school and job success. Table 1 shows correlations that have been obtained by comparing JTPT to theory tests, and to job-knowledge tests. The latter two are paper-and-pencil tests. Table 1 also includes correlations of JTPT with school marks. As indicated earlier, school marks have been heavily weighted with the paper-and-pencil test scores. An examination of this table indicates that the correlations of JTPT scores with theory test scores are generally somewhat lower than with job-knowledge tests. None of these measures is sufficiently valid for use as substitutes for JTPT (Foley, 1967, 1974).

The personnel system, which includes formal training, depends almost exclusively on such paper-and-pencil tests for making initial selection, for ascertaining effectiveness of training and for the promotion of maintenance personnel. The effectiveness of formal training for the mechanical maintenance specialties is measured mainly by scores obtained from such paper-and-pencil job knowledge tests, even though the students in these training programs have received at least some "hands-on" practice on many mechanical maintenance tasks. The measures of effectiveness of formal training programs for the electronic maintenance specialties include scores from paper-and-pencil job knowledge tests, as well as theory tests. Students in these electronic maintenance courses receive little if any "hands-on" practice in their maintenance tasks.

The selection tests for both mechanical and electronic maintenance specialties have been standardized against composite scores from paper-and-pencil tests. This means that the people selected for the maintenance specialties have been selected not on their aptitude for performing the tasks of their maintenance jobs, but on their aptitude for making high scores on paper-and-pencil, theory and job knowledge tests.

The specialty knowledge test (SKT) and the promotion fitness examination (PFE) used for advancement up the maintenance career ladders also are paper-and-pencil job knowledge tests. At the present time, throughout his whole career, a maintenance specialist is not required to demonstrate on formal JTPTs that he can efficiently and effectively perform the tasks of his job.

IV. THE MAN-MACHINE INTERFACE FOR MAINTENANCE

The maintenance R&D supported by AS has emphasized the man-machine interface. From this point of view, PM for all personnel *associated* with machine systems must determine the ability of such personnel to perform tasks generated by the man-machine *interface.* Although there may be some overlap, most of the task functions demanded by a machine system of its operator personnel are *different* from those task functions demanded of its maintenance personnel. Herein, lies most of the unique, distinguishing characteristics of PM for maintenance. As a result, this section of my paper will be devoted to a discussion of the complexity of maintenance task functions.

Past Human Factors Emphasis

But before discussing the characteristics of *task functions* for maintenance, it might be well to call attention to the fact that human factors establishments have given much more attention to the operator interface with machines than to the maintenance personnel interface. Many actions are taken to maximize effective and efficient performance of the operator. Work stations are human engineered to maximize the efficiency and comfort of the human operator. Major training facilities are provided, so that, operators can

Table 1. **Correlations Between Job-Task Performance Tests and Theory Tests, Job Knowledge Tests, and School Marks**

Researchers	Type of Job Task Performance Test (JTPT)	Theory Tests	Job Knowledge Tests	School Marks
Anderson (1962)	Test Equipment JTPT			.18–.33
Evans and Smith (1953)	Troubleshooting JTPT	.24 & .36	.12 & .10	.35
Mackie et al., (1953)	Troubleshooting JTPT	.38		.39
Saupe (1955)	Troubleshooting JTPT		.55	.56
Brown et al., (1959)	Troubleshooting JTPT	.40		
	Test Equipment JTPT		.29	
	Alignment JTPT		.28	
	Repair Skills JTPT		.19	
Williams and Whitmore (1959)	Troubleshooting JTPT			
	(Inexperienced Subjects)	.23		
	(Experienced Subjects)	.15		
	Adjustment JTPT			
	(Inexperienced Subjects)	.02		
	(Experienced Subjects)	.21		
	Acquisition Radar JTPT			
	(Inexperienced Subjects)	.03	.36	
	(Experienced Subjects)	.14	.22	
	Target Tracking Radar JTPT			
	(Inexperienced Subjects)	.24	.33	
	(Experienced Subjects)	.20	.38	
	Missile Tracking Radar JTPT			
	(Inexperienced Subjects)	.09	.15	
	(Experienced Subjects)	.19	.32	
	Computer JTPT			
	(Inexperienced Subjects)	.08	.24	
	(Experienced Subjects)	.06	.14	
	Total JTPT			
	(Inexperienced Subjects)	.14		
	(Experienced Subjects)	.20		
Crowder et al., (1954)	Troubleshooting JTPT	.11	.18–.32	

receive a large amount of supervised practice in performing typical tasks of their job. Graduation from training is based primarily on demonstrated ability to perform job tasks. And, periodic checks are made of the operator's ability to perform the critical tasks of his job. These, of course, are not all of the many efforts made to maximize the performance of human operators.

Generally, the human factors establishment has given little attention to the effectiveness and efficiency of the maintenance man's interface with hardware. The maintenance work of AS, including the PM work, has emphasized this neglected interface, but typically, this part of our program has received little management visibility or support.

The Structure of the Man-Machine Interface for Maintenance

One of the results of our R&D for maintenance has been the evolution and articulation of a structure for handling maintenance functions and their complex relationships in a systematic manner. This structure includes (a) standard maintenance functions and action verbs, (b) a working definition of a maintenance task, and (c) schemes for handling the complexities of maintenance tasks.

Standard Maintenance Functions and Action Verbs. The establishment of standard maintenance functions and action verbs has been one of the widely accepted results of the Air Force Systems Command's (AFSC) job performance aids (JPA) effort entitled "Presentation of Information for Maintenance and Operation" (PIMO). (Although the PIMO project was managed by the Space and Missile Systems Organization (SAMSO) of AFSC, AS provided active participation and technical inputs during the entire project from 1966 through 1969. AS has incorporated the key findings and outputs of PIMO in its own JPA efforts). Early in the PIMO project, it was found that many maintenance action verbs and functions were used by maintenance people, some with several different meanings. Part of this confusion was caused by the language used in maintenance technical orders which were written by different people and produced by many different hardware manufacturers. As a result, maintenance technicians themselves did not generally use precise language. A study was made to identify and define these action verbs. Where two or more verbs were used to indicate a similar action, the preferred verb was selected based on the expressed preferences of a sample of maintenance men with a wide range of

maintenance Air Force specialty code (AFSC). The use of the preferred verbs of this list is now a firm requirement of Air Force technical order specifications, as well as of recent Army and Navy specifications (see Joyce, Chenzoff, Mulligan, & Mallory, 1973, pp. 97–142).

A Working Definition of a Maintenance Task. Within this list of action verbs are a number of key action verbs (functions). A key action verb, with an appropriate specific hardware unit as its predicate, becomes a *task statement.* Such a task statement represents a maintenance task which can be demanded by the existence and operation of a specific machine subsystem. A list of these functions is found in AFHRL-TR-73-43(I) (Joyce et al., 1973, pp. 19–20). This list includes functions which are found in both mechanical and electronic jobs. Some apply to only mechanical jobs and some apply to both.

Schemes for the Systematic Consideration of Maintenance Functions and Tasks. Three schemes have been developed for the systematic consideration of maintenance functions and tasks, and the key factors that affect them.

Scheme One. A convenient model for categorizing these maintenance functions with relation to the type of hardware and the level of maintenance is presented in Figure 1. The common maintenance functions already mentioned together

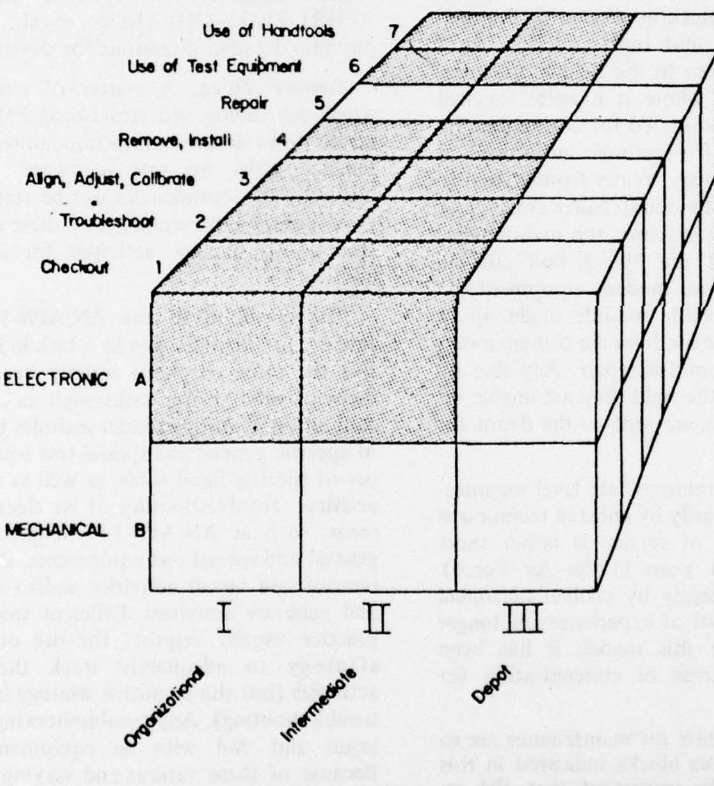

Figure 1. **A functional representation of the DOD maintenance structure (shaded portion indicates scope of AFHRL PM development for electronic maintenance).**

with use usage of test equipment and handtools are represented on one axis of the model. Since mechanical and electronic subsystems usually require a different variety of maintenance actions, they are represented by another axis. (In regard to this axis, mechanical maintenance could be further divided into two categories, *one* represented by hardware such as jet engines and *another*, by hardware such as airframes, and tank and ship hulls).

The third axis of the model represents the three levels or categories of maintenance now found in the military services. Organizational maintenance is the first level. It is usually aimed at checking out a whole machine subsystem and correcting any identified faults as quickly as possible. Flight line maintenance falls in this category. A system is checked out. If it does not work, the line replaceable unit (LRU) or "black box" causing the malfunction is identified and replaced. This major component is then taken to the field shop (intermediate maintenance) where it is again checked out and the faults, authorized for correction, are corrected. The corrective actions, authorized at the intermediate level, vary greatly from system to system depending on the maintenance concept of each system. On some systems, the maintenance man will troubleshoot the "black box" to the piece part level. In more modern equipment, he will identify a replaceable module made up of many piece parts. Some modules are thrown away, others sent to the depot for repair. Any line replaceable units which the field shop are unable, or unauthorized, to repair are sent to the depot for overhaul.

Organizational and intermediate level organizations are manned primarily by enlisted technicians whose average length of service is rather short (slightly more than 4 years in the Air Force). Depots are manned largely by civilian personnel with a much higher level of experience and longer retention time. Using this model, it has been possible to specify areas of concentration for study.

Since PM requirements for maintenance are so different for the various blocks indicated in this model, it is extremely important that PM researchers indicate the precise blocks of their concentration. To date, AS has concentrated on the shaded electronic portions of this model (Figure 1). The resultant model battery of 48 JTPT together with their symbolic substitutes will be described later. In addition, a battery of eleven JTPT was developed on an *ad hoc* basis (Shriver & Foley, 1975) for mechanical tasks at the organizational level of maintenance (see shaded portion of Figure 2). The HumRRO work, mentioned previously (Vineberg et al., 1970a, 1970b; Vineberg & Taylor, 1972a, 1972b) was concerned with mechanical hardware (tank and truck). The thirteen tests developed concerned the maintenance functions which are indicated by the shaded portions of Figure 3.

Scheme Two. Maintenance functions have limited meaning unless applied to specific hardware. A task identification matrix (TIM) is an extremely effective and necessary device for interfacing these maintenance functions with the appropriate hardware units and thus identifying the maintenance tasks that are generated by a specific machine subsystem (see Figure 4). The TIM, when properly structured, will reflect the maintenance level or levels of interest, that is organizational, intermediate and/or depot. AFHRL-TR-73-43(I) (Joyce et al., pp. 16–37) provides detailed directions for developing a TIM.

Scheme Three. A matter of *serious* concern when developing and structuring PM for maintenance tasks is the interaction among the maintenance tasks for *one* hardware. A four-level hierarchy of dependencies can be stated. Figure 5 gives a graphic presentation of these dependencies among maintenance activities for an electronic hardware.

The checkout of the AN/APN-147 (Doppler Radar), for example, can be a task in its own right. But the same checkout activity becomes an element of other major tasks such as calibrate. The calibration of doppler radar includes the operation of specific general and special test equipments, the use of specific hand tools, as well as the checkout activity. Troubleshooting of an electronic equipment; such as AN/APN-147, requires the use of general and special test equipments. It may require remove and install activities and/or adjust, align, and calibrate activities. Efficient troubleshooting practice usually requires the use of a cognitive strategy to adequately track the dependent activities (but the cognitive strategy in itself is not troubleshooting). Any troubleshooting task should begin and end with an equipment checkout. Because of these various and varying dependency relationships, such activities as checkout, remove, install, disassemble, adjust, align, calibrate, or troubleshoot cannot legitimately be considered as discrete tasks, even for one electronic system.

Another confounding factor is the false correspondence that the same functional verbs create when applied to *different* electronic hardware. For example, personnel with the Avionic Inertial and Radar Navigation Systems Specialist, AFSC

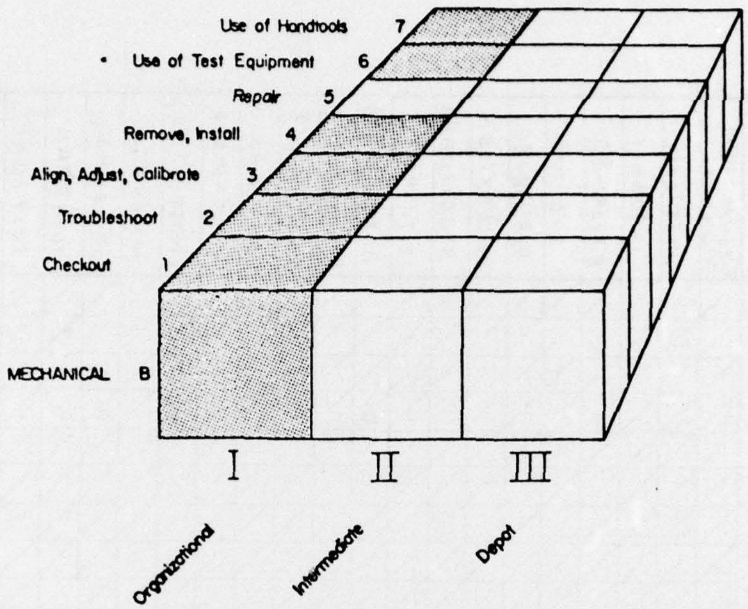

Figure 2. **A functional representation of the stops of AFHRL PM development for mechanical maintenance.**

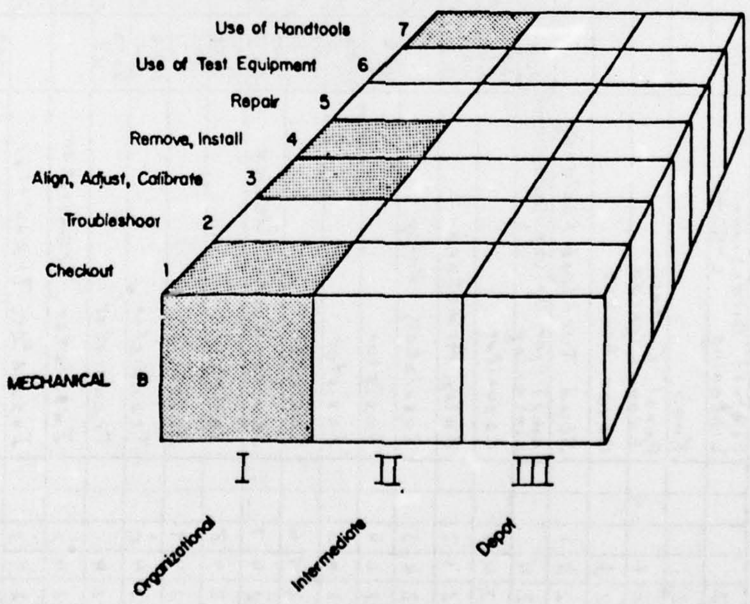

Figure 3. **A functional representation of the scope of the HumRRO PM development for mechanical maintenance (Vineberg et al., 1970b).**

Found in Troubleshooting	Code						System Hardware Item	Reference Designator	1 Adjust	2 Align	3 Calibrate	4 Checkout/Troubleshoot	5 Clean	6 Disassemble/Assemble	7 Inspect	8 Lubricate	9 Operate	10 Remove/Install	11 Repair	12 Service	13	Notes
									Maintenance Function													
✓	1	2					Control, Directional Listening C-8246	10	-	I*	-	I	I	I	-	-	-	O	I	-		*Resolver 1U31 Alignment
	1	2	1				Knob		-	-	-	-	-	-	I	-	-	I	-	-		147971-1
	1	2	2				Panel, Control - Edge Lighted		-	-	-	-	-	-	I	-	-	I	-	-		159024-1
	1	2	3				Cover, Access		-	-	-	-	-	-	-	-	-	I	-	-		839691-801
	1	2	3	1			Stud, Turnlook Fastener			-	-	-	-	-	I	-	-	D	-	-		2-0-100
✓	1	2	4				Amplifier, Driver-Directional Listening	10A2	-		-	D	-		-	-	-	I	-	-		718436-801
✓	1	2	4	1			Capacitor	10A2 C15	-	-	-	-			-		-	D	-	-		CK06BX105K
✓	1	2	4	2			Relay, Armature	10A2 K1	-	-	-	-	-	-			-	D	-	-		35BC1206A2
	1	2	4	3			Insulator, Relay		-	-	-	-	-	-	-	-	-	D				7717-129N
✓	1	2	4	4			Resistor	10A2 R1	-	-	-	-	-	-	-	-	-	D	-	-		RCR07G223J3
✓	1	2	4	5			Resistor	10A2 R2	-	-	-	-	-	-	-	-	-	D		-		RCR07G223J3
✓	1	2	4	6			Resistor	10A2 R3	-	-	-	-	-	-	-		-	D	-	-		RCR07G105J3
✓	1	2	4	7			Semiconductor Device	10A2 CR5	-	-	-	-	-	-	-	-	-	D	-	-		JAN1N645
✓	1	2	4	8			Resistor	10A2 R32	-	-	-	-	-	-	-	-	-	D	-	-		RN55D1783F
✓	1	2	4	9			Capacitor	10A2 C5	-	-	-	-	-	-	-	-	-	D	-	-		CM05FD221J03
✓	1	2	4	10			Transistor	10A2 Q4	-	-	-	-	-	-	-	-	-	D	-	-		JAN2N930
✓	1	2	4	11			Transistor	10A2 Q3	-	-	-	-	-	-	-	-	-	D	-	-		JAN2N930
	1	2	4	12			Insulator, Transistor		-	-	-	-	-	-	-	-	-	D	-	-		10197DAP
	1	2	4	13			Insulator, Transistor		-	-	-	-	-	-	-	-	-	D	-	-		10197DAP
✓	1	2	4	14			Capacitor	10A2 C13	-	-	-	-	-	-	-	-	-	D	-	-		CK06BX104K

Figure 4. Example of a task identification matrix (TIM). Cell entries: – (dash) no maintenance task of this type is performed on this hardware item; 0 – task of type, performed at organizational level; I – task, performed at intermediate level; and D – task, performed at depot level.

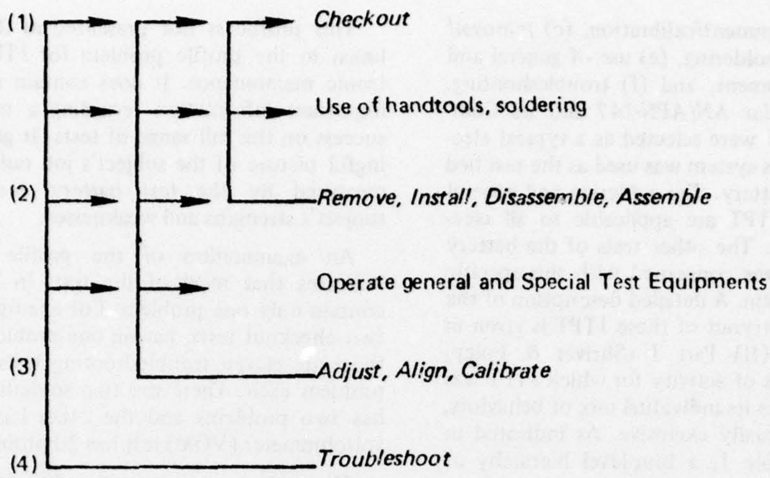

Figure 5. **Indicating the dependencies among maintenance functions for electronic hardware (functions italicized).**

328X4, are maintaining at least 50 major electronic subsystems. Many vintages of hardware design are represented. The checkout activity for each is different (both in content and difficulty) and in some cases, very different. The lack of correspondence of alignment, calibration, and troubleshooting tasks from one specific equipment to another is even greater. An example of the lack of correspondence from one hardware to another is the wide difference in the content and difficulty of troubleshooting tasks between two doppler radars. The AN/APN-147, which is used on the C-130 and C-141, has approximately 14,000 shop replaceable units (SRU) whereas the inertial doppler navigation equipment (IDNE) on the C-5 has only 28. This lack of correspondence of functions across electronic hardware makes it difficult to generalize from results of PM from one electronic hardware to another. One exception is in the area of general test equipment which may be used in performing maintenance tasks across many hardware subsystems.

The examples given are characteristic of many of the electronic maintenance AFSCs. Similar problems in complexity of maintenance functions and tasks are found in mechanical hardware, but to a lesser degree.

V. DEVELOPMENT OF PM AND SYMBOLIC SUBSTITUTES FOR PM

Starting in 1969, AS supported a modest program to provide the Air Force with the necessary tools for measuring the ability of maintenance personnel to perform the *key tasks* of their jobs. The scope of this work was limited to the maintenance of electronic hardware at the organizational and intermediate levels (see shaded portion of Figure 1). This program had two objectives: (a) to develop a model battery of JTPT together with appropriate scoring schemes for the measurement of the task performance ability of electronic maintenance personnel (an effort was to be made for the development of JTPT which could be easily administered), and (b) using the JTPT of this battery as criteria, to develop and try out a series of paper-and-pencil symbolic substitute tests that would hopefully have high empirical validity.

Criterion Referenced Job Task Performance Tests

A model battery of 48 criterion referenced JTPT and a test administrator's handbook were developed for measuring ability to perform electronic maintenance tasks. Copies of the actual instructions for test subjects together with the test administrator's handbook are available from the Defense Documentation Center (DDC) as AFHRL-TR-74-57(II) Part II (Shriver, Hayes, & Hufhand, 1975). The test administrator's handbook was developed with step-by-step detailed instructions so that an individual with a minimum of electronic maintenance experience can administer the tests.

The battery includes separate tests for the following classes of job activities: (a) equipment

checkout, (b) alignment/calibration, (c) removal/replacement, (d) soldering, (e) use of general and special test equipment, and (f) troubleshooting. The Doppler Radar AN/APN-147 and its Computer AN/ASN-35 were selected as a typical electronic system. This system was used as the test bed for this model battery. The soldering and general test equipment JTPT are applicable to all electronic technicians. The other tests of the battery apply to technicians concerned with this specific doppler radar system. A detailed description of the development and tryout of these JTPT is given in AFHRL-TR-74-57(II) Part I (Shriver & Foley, 1974a). Each class of activity for which JTPT was developed contains its individual mix of behaviors, but it is not mutually exclusive. As indicated in Figure 5 and Table 1, a four-level hierarchy of dependencies exists among them.

After considering product, process, and time as to their appropriateness for scoring the results for each activity, it was decided that a test subject had not reached criterion until he had produced a complete, satisfactory product. This was a go, no-go criterion.

Table 2 summarizes the number of tests, problems and scorable products by class developed for the AN/APN-147 and AN/ASN-35. The simple addition of numbers shown in Table 2 indicates that there are 48 tests, 81 problems, and 133 scorable products. But, these numbers tell us nothing in terms of the content of the tests. To say that one test subject accomplished 100 scorable products while another accomplished 90, tells us nothing about the job readiness of these individuals or that one is better than the other. The varieties of scorable products are so diverse that any combination of them, without regard to what they represent, is meaningless. The only meaningful presentation of such information must be in terms of a profile designed to attach meaning to such numbers. A sample of such a profile is shown in Figure 6.

This profile is not presented as the final solution to the profile problem for JTPT for electronic maintenance. It does contain most of the important information regarding a test subject's success on the full range of tests. It gives a meaningful picture of the subject's job task abilities as measured by the test battery, indicating the subject's strengths and weaknesses.

An examination of the profile (Figure 6) indicates that most of the tests in this battery contain only one problem. For example, there are two checkout tests, having one problem each and there are eleven troubleshooting tests having one problem each. There are two soldering tests; one has two problems and the other has three. The voltohmmeter (VOM) test has 20 problems.

The subject receives no "credit" for a problem unless he obtains all of the expected products. No attempt is made to combine these scores in terms of meaningless numbers.

The hierarchy of dependencies discussed previously (Figure 5) has implication for the order in which tests are administered, as well as for diagnostics. For example, since troubleshooting includes the use of test equipment and other activities in the hierarchy, logic would dictate that in most training situations the administration of the tests for the sub-activities would precede the troubleshooting tests and that a test subject would not be permitted to take the troubleshooting tests until he had passed these other subtests. Under some circumstances, one may wish to reverse the process. A subject who successfully completes selected troubleshooting or alignment tests can be assumed to be proficient in his use of test equipment and checkout procedures. These dependencies are displayed on the left-hand side of the profile (Figure 6).

Due to the unavailability of a sufficient number of experienced test subjects at the time of the tryout of the JTPT battery, the tryout was not as

Table 2. **Tests, Problems, and Scorable Products**

Class	Code	Tests	Problems	Scorable Products
1. Checkout	CO	2	2	2
2. Physical Skill Tasks (soldering)	PT	2	5	17
3. Remove and Replace	RR	10	10	20
4. Test Equipment	SE	7	37	67
5. Adjustment	AD	6	6	6
6. Alignment	AL	10	10	10
7. Troubleshooting	TS	11	11	11
Total	7	48	81	133

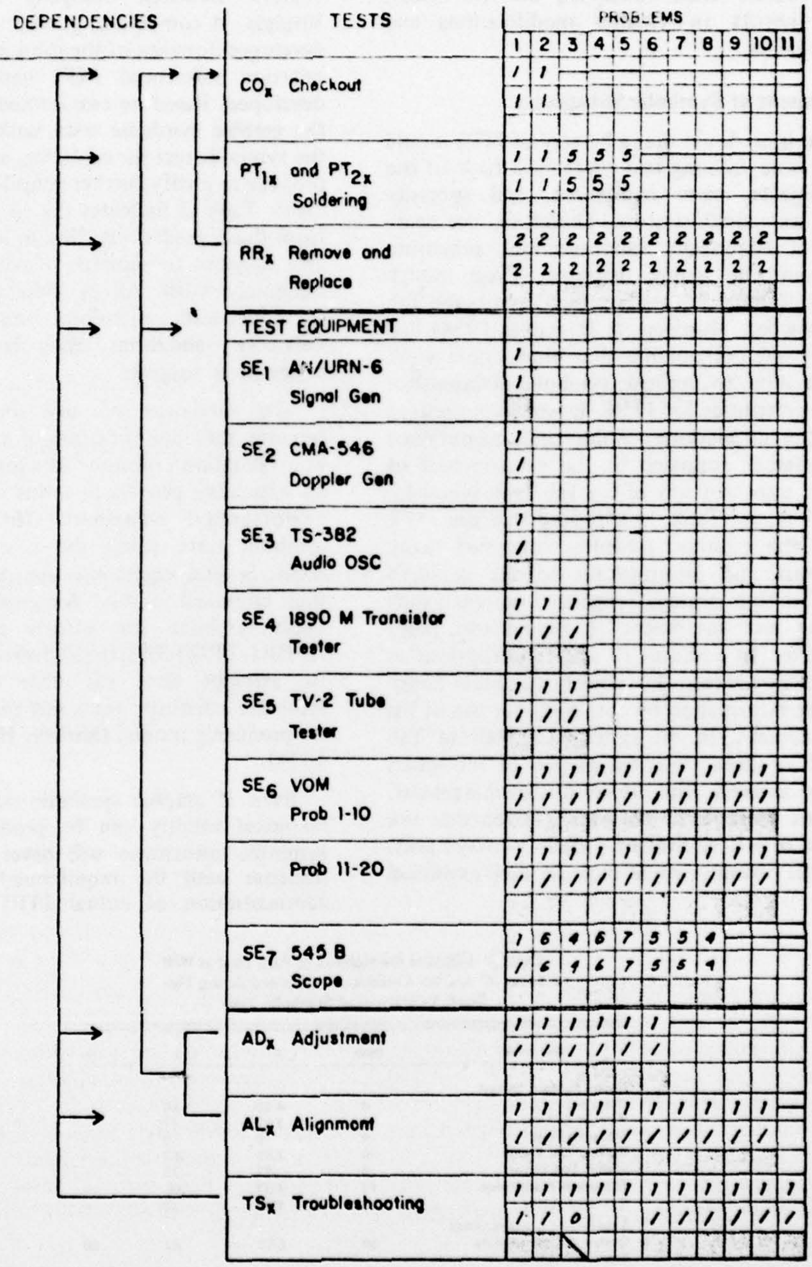

Figure 6. **A profile for displaying the results obtained by an individual subject from a battery of Job Task Performance Tests concerning an electronic system – the AN/APN-147 and the AN/ASN-35. This represents the profile of an individual who has successfully completed most of the battery.**

extensive as planned. The limited tryout did indicate that the tests as developed are administratively feasible. Their continued use, no doubt, would result in further modifications and improvements.

Development of Symbolic Substitutes

There is no doubt that a battery of JTPT would require more training and on-the-job time of the test subjects, more equipment, and specially trained test administrators. Therefore, the availability of empirically valid symbolic substitute tests would be highly desirable. Even though previous attempts to develop such tests as the Tab Test (Crowder, Morrison, & Demaree, 1954) had failed, it was our opinion that much more work could be done to improve symbolic maintenance tests as substitutes for JTPT. It was hypothesized that higher correlations possibly could be obtained by a different approach to the development of symbolic tests. A study of the Tab Tests (Crowder et al., 1954, see Table 1) indicated that the JTPT used as the criterion measures contained many distractions and interruptions to the subject's troubleshooting strategy (cognitive process); such as, using test equipment to obtain test point *information. In addition to such interruptions* to the cognitive process, the subject can obtain faulty test point information by the improper use of his test equipment. In the symbolic substitute Tab Tests, all of these potential pitfalls of the actual task were avoided. The subject was given a printed test point readout. It was hypothesized that the injection of job equivalent pitfalls into symbolic substitutes possibly would increase their empirical validity.

Based on these hypotheses, a battery of symbolic tests was developed under contract with the Matrix Research Company of Falls Church, Virginia. A companion graphic symbolic test was developed for each of the job activities for which a criterion referenced JTPT had previously been developed. Based on two limited validations, all of the graphic symbolic tests, with the exception of the symbolic test for soldering, indicated sufficient promise to justify further consideration and refinement. Table 3 indicates the correlations obtained from these validations. Due to a shortage of available subjects, the number of pairs of subjects was extremely small. All of these promising graphic symbolic tests, therefore, must be given more extensive validations using larger numbers of experienced subjects.

The validation of any such symbolic test requires the administration of a companion JTPT as a validation criterion. As a result, a validation is an expensive process in terms of equipment and experienced manpower. The troubleshooting symbolic tests require the most extensive refinement. Several suggestions are made for improving their empirical validity. A complete description of these symbolic test efforts can be found in AFHRL-TR-74-57(III) (Shriver & Foley, 1974b). An attempt, also, was made to develop video symbolic substitute tests, but this effort produced no promising results. (Shriver, Hayes, & Hufhand, 1974).

Even if graphic symbolic substitutes of high empirical validity can be produced, the use of symbolic substitutes will never, in my opinion, dispense with the requirement for the liberal administration of actual JTPT to maintenance

Table 3. **Indicates the Number of Pairs Used as Well as the X^2 and the Correlations Obtained during Two Small Validations of Symbolic Tests**

Test Area	N Pairs	X^2	ϕ	r_t
Novice Subjects (Altus)				
Checkout	4	4.00	1.00	–
Remove & Replace	14	2.57	.43	–
Soldering Tests	4	0	0	–
General Test Equip	6	2.67	.67	–
Special Test Equip	6	.67	.33	–
Alignment/Adjustment	19	6.37	.58	–
Troubleshooting	9	1.00	–.33[a]	–
Experienced Subjects (TAC)				
Overall Troubleshooting	30	6.53	.47	.68
Chassis (Black box)				
Isolation	30	16.33	.73	.81
Stage Isolation	30	3.33	.33	.46
Piece/Part Isolation	15	.07	.07	.16

[a]This negative correlation was probably due to a number of deficiencies such as (1) deficiencies in the Fully Proceduralized Job Performance Aids provided the subjects, (2) deficiencies in the sequencing of the troubleshooting JTPT in relation to the sub-tests in the JTPT battery, (3) maintenance difficulties with the AN/APN-147 AN/ASN-35 system, and (4) difficulties with the content and administration of test equipment pictorials provided in the original troubleshooting symbolic tests.

personnel. We can never include all aspects of an actual performance of a task in a paper-and-pencil symbolic representation of that task, but our work indicates that we can come much closer than has been done in the past.

The Sampling Problem

Timewise, it would be impossible to administer a JTPT to a maintenance man for every possible task that his hardware system might produce. This world of tasks and people must be sampled. The model battery described previously provides a sampling procedure based on major task functions such as checkout, align, adjust, troubleshoot, etc. But even this sampling across possible tasks resulted in *48* tests and 133 scorable products (Table 2). It would be impractical to give any one test subject all of these 48 tests at any one time. Systematic sampling schemes must be developed across tests.

The purposes for which JTPT results are to be used should be considered when developing sampling schemes. Such purposes could include ascertaining (a) the job task proficiency of an individual, (b) the job effectiveness of a training program, and (c) the proficiency of a maintenance unit. Each of these purposes would require a different mix or mixes of tests and people. Some suggestions for such samplings can be found in AFHRL-TR-74-57(II) Part I (Shriver & Foley, 1974a). But it should be remembered that these are suggestions that must still be field tested.

In the case of determining unit proficiency, some JTPT can be administered by on-line observation of tasks which are often repeated such as checkout. There will always be a requirement for off-line PM concerning critical, but seldom performed tasks. Whether the JTPT is performed on-line or off-line, the test administrator must use the same objective scoring procedures, the criteria of success being acceptable *products.*

VI. CONSOLIDATED DATA BASE TO SUPPORT PM

In keeping with its man-machine interface orientation, AFHRL/AS is demonstrating the technical feasibility of integrating five human resources related technologies and applying them during weapon system development. This is being accomplished under project 1959, "Advanced System for the Human Resources Support of Weapon System Development." The five technologies are: (a) human resources in design trade offs, (b) maintenance manpower modeling, (c) job performance aids, (d) instructional system design, and (e) system ownership costing.

One objective of this program is to determine the data input requirements for and prepare specifications for a consolidated maintenance task identification and analysis data base which will support the integrated application of these five technologies in a weapon system development program. We feel that such a consolidated data base will contain most, if not all, of the information which would be required to develop good JTPT provided the tests are developed in keeping with the technology described in this paper. If such a data base is demonstrated to be technically feasible and if it is routinely made a requirement in weapon system development contracts, it will provide considerable assistance in developing maintenance performance tests for new weapon systems.

VII. INSTITUTIONALIZATION OF NEW TECHNOLOGIES

Getting newly developed technologies such as PM institutionalized is a perennial problem, especially, when a technology requires fundamental changes in long existing programs, procedures, and attitudes of entrenched establishments. AS has been involved in the implementation of several well developed and documented technologies, such as job performance aids and instructional systems design (ISD) including programmed instruction and job (task) oriented training. These experiences have indicated that it is extremely difficult to maintain the integrity of a technology during its so-called implementation. Operational organizations invariably attempt to implement a much "watered down" version of the technology and consequently obtain much "watered down" results. In some cases only cosmetic changes to existing programs are reported as implementations. Currently it requires years of persistent effort on the part of the research community to get a technology properly institutionalized.

A mechanism must be developed for the timely institutionalization of each new technology which will ensure its integrity. A mechanism for the orderly implementation of technologies, similar to that used for new weapons systems, is recommended. Such a mechanism must make efficient and effective use of the "know-how" of the developers of the technology and make them

responsible and accountable for its implementation. A new technology should not be turned over to a using command for its operation until it is in place, "debugged" and operational–just as a new weapons system is not turned over to an operational command until it has been "debugged" and proven to be ready for operational use.

VIII. PROPOSED PM R&D EFFORTS FOR MAINTENANCE

Excessive maintenance costs are never going to be reduced as long as we don't have JTPT and/or empirically valid symbolic substitutes to ascertain how efficiently maintenance men perform the *tasks* of their jobs. In my opinion, the lack of such measures of maintenance performance is a most serious *deficiency* in DOD. As such, R&D in this area should have an extremely high priority.

Areas for R&D Concentration

For a long range R&D effort, five general areas of concentration are recommended; namely JTPT and matching symbolic substitute tests for electronic maintenance, JTPT and matching symbolic substitute tests for mechanical maintenance, and aptitude tests based on PM. The development and field tryout of a JTPT must precede the development of its symbolic substitute. The work on JTPT batteries for both electronic and mechanical maintenance should be started as soon as possible. The work on aptitude tests should not be started until JTPT batteries and the symbolic substitute tests have been completely field tested. More information concerning these areas of concentration follows:

1. *Refinement of Model JTPT Battery (Electronic Maintenance).* The already available model JTPT Battery (Shriver, Hayes, & Hufhand, 1975) should be given a large scale *field* tryout. (Since the AB328X4 Avionic Inertial and Radar Navigation Systems Specialist Course, which includes the AN/APN-147 and the AN/ASN-35, does not emphasize the mastery of job tasks, the equipment-specific tests of this battery cannot be used in the formal course.) One thrust of this effort should be to further refine the battery including its administrative procedures. A second thrust should be the development of sampling strategies which would be appropriate for determining the effectiveness of training programs and both individual and unit proficiency as discussed earlier under PM problems. This effort would require approximately two professional man-years plus the use of maintenance specialists as test administrators from the appropriate maintenance specialties. If it is necessary to select a system other than the AN/APN-147-AN/AJN-35 combination, this work would require approximately four professional man-years.

2. *Refinement of Symbolic Substitutes (Electronic Maintenance).* As previously indicated, a number of symbolic substitutes for JTPT were developed and given a limited tryout. Table 3 indicated that some of the symbolic tests show promising empirical validity. These promising symbolic tests must be more thoroughly refined and validated. In addition, further exploratory development is required for symbolic substitute tests for troubleshooting tasks in keeping with recommendations made in AFHRL-TR-74-57(III) (Shriver & Foley, 1974b). This effort would require between three and four professional man-years *plus* the use of maintenance specialists as test administrators and test subjects from the appropriate maintenance specialties.

3. *Development of Model JTPT Battery (Mechanical Maintenance).* A model JTPT battery similar to the model battery for electronic maintenance described previously should be developed for a typical mechanical subsystem such as a jet engine or tank engine covering both the organizational and intermediate levels of maintenance. This model should be thoroughly field tested. Sampling strategies as indicated for the electronic battery should also be developed. This effort will require approximately four professional man-years *plus* the use of maintenance men from the appropriate maintenance specialties as test administrators and test subjects.

4. *Development of Symbolic Substitutes (Mechanical Maintenance).* An attempt should be made to develop symbolic substitute tests with high empirical validity after the model JTPT battery is available for mechanical maintenance. The same contractor should develop these symbolics as developed the JTPT battery. A very rough estimate for accomplishing this symbolic effort would be four professional man-years.

5. *Job Aptitude Test Research Based on Results on JTPT.* R&D plans should be made to utilize the results of JTPT and symbolic substitute tests for standardizing military aptitude indices obtained from the Armed Services Vocational Aptitude Battery (ASVAB). *As a first step*, the military aptitude scores of all tests subjects used for the tryouts in the proposed JTPT R&D should

be recorded. In addition, such aptitude scores should be obtained during any school or field administration of JTPT or symbolic substitutes. When sufficient data are obtained, the degree of relationship between JTPT results and various aptitude indices should be obtained. *Later*, when a sufficient number of JTPT are used in the field, a formal R&D project should be initiated to modify the ASVAB to directly reflect job success as measured by JTPT.

R&D Strategy. Probably the most cost-effective approach for PM for both electronic and mechanical maintenance would be to concentrate on the development and refinement of JTPT on use of *key test equipments* prior to proceeding with the other task functions of the proposed model test batteries. As indicated in Figure 5, the use of general test equipment is a prerequisite to maintenance task functions such as alignment, calibration and troubleshooting. In addition, general test equipments usually have wide usage in such task functions across many hardware systems and there are substantial amounts of data which indicate that many maintenance men are weak in their test equipment ability. So, a general improvement in ability to use test equipment is an important and necessary factor for the general improvement of several maintenance task functions. I would strongly recommend, therefore, that the early concentration for the proposed model test batteries in this area. Each PM development for a test equipment should be accompanied by the development of a programmed training package with sufficient practice frames for teaching the mastery of all its functions. Basic models of such training packages for 12 general test equipments are now available (see Scott & Joyce, 1975a through 1975l). However, more practice frames should be included in these programs.

IX. CLOSING STATEMENT

Maintenance of hardware is currently an extremely costly operation for the DOD. High maintenance cost is the primary cause of high systems ownership cost. For some electronic maintenance specialties, nearly one year of broad formal training is given first enlistment personnel. And maintenance training generally is long and costly. Even with such lengthy training, the efficiency of maintenance could be greatly improved. Improved job instructions and information as well as increased use of job (task) oriented training have great potential for decreasing maintenance training time and improving the job performance of maintenance tasks. But to realize such potential, the criteria for the personnel system (selection, training, assignment and promotion) for maintenance personnel must be shifted to the demonstrated ability to perform the tasks of their jobs. (The current criteria emphasize the ability to obtain high scores on paper-and-pencil theory and job knowledge tests.)

In this paper, I have discussed what I think are the important aspects of the criterion problem as it applies to the measurement of ability to perform maintenance tasks in training and on the job. Our objective in its solution is to get as close to the real job as possible. When "on-line" tasks occur often enough, their structured observation may be appropriate. *But* when such observations are not appropriate or when tasks occur infrequently, we propose to have the tasks performed "off-line" in a job-like environment. Our approach to the development of such measures was started with an analysis of the structure maintenance of the man/hardware interface. Based on the results of this analysis, we developed a model test battery of JTPT for electronic maintenance. Using this model as the criterion, we also developed batteries of graphic and video symbolic substitute tests. Several of the graphic symbolics have indicated respectable empirical validities but require more refinement and tryout. Our attempts to develop video symbolics were unsuccessful.

I have recommended a research program based on what we have already accomplished. This includes the development of a model battery of JTPT together with symbolic substitutes for maintenance tasks generated by a typical mechanical hardware. I have, also, discussed briefly the perennial problem of getting new technologies such as JTPT implemented. There is definitely a requirement for a structured mechanism which will guarantee the orderly institutionalization of such technologies as well as their integrity during the institutionalization process.

REFERENCES

Anderson, A.V. *Training, utilization and proficiency of Navy electronics technicians: III. Proficiency in the use of test equipment.* Navy Technical Bulletin 62-14, AD-294 330. San Diego: U.S. Navy Personnel Research Activity, 1962.

Brown, G.H., Zaynor, W.C., Bernstein, A.H., & Shoemaker, H.A. *Development and evaluation of an improved field radio repair course.* Technical Report 58, Project Repair. AD 227 173. Washington, DC: Human Resources Research Office, The George Washington University, 1959.

Crowder, N., Morrison, E.J., & Demaree, R.G. *Proficiency of 0-24 radar mechanics: VI. Analysis of intercorrelations of measures.* AFPTRC-TR-54-127, AD-62 115. Lackland AFB, TX: Air Force Personnel and Training Research Center, 1954.

Evans, R.N., & Smith, L.J. *A study of performance measures of troubleshooting ability on electronic equipment.* Illinois: College of Education, University of Illinois, October 1953.

Foley, J.P., Jr. *Critical evaluation of measurement practices in post-high school vocational electronic technology courses.* AD-683 729. Doctoral dissertation, University of Cincinnati, 1967.

Foley, J.P., Jr. *Evaluating maintenance performance: An analysis.* AFHRL-TR-74-57(I), AD-A004 761. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, October 1974.

Frederiksen, N. Proficiency tests for training evaluation. In R. Glaser (Ed.), *Training research and education.* Pittsburgh, PA: University of Pittsburgh Press, 1962.

Jenkins, J.G. Validity for what? *Journal of Consulting Psychology*, March–April 1946.

Joyce, R.P., Chenzoff, A.P., Mulligan, J.F., & Mallory, W.J. *Fully proceduralized job performance aids: Draft military specification for organization and intermediate maintenance.* AFHRL-TR-73-43(I), AD-775 702. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, December 1973.

Mackie, R.R., Wilson, C.L., & Buckner, D.N. *Practical performance test batteries for electricians mates and radiomen developed in conjunction with a manual for use in the preparation and administration of practical performance tests.* AD-98 239. Los Angeles, CA: Management and Marketing Research Corporation, June 1953.

Saupe, J.L. *An analysis of troubleshooting behavior of radio mechanic trainees.* AFPTRC-TN-55-47, AD-99 361. Lackland AFB, TX: Air Force Personnel and Training Center, November 1955.

Scott, D.L., & Joyce, R.P. *TEKTRONIX 545B oscilloscope training.* AFHRL-TR-76-19, AD-A022 941. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, September 1975.(a)

Scott, D.L., & Joyce, R.P. *TS-1100/U transistor tester training.* AFHRL-TR-76-20, AD-A022 930. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, September 1975.(b)

Scott, D.L., & Joyce, R.P. *TS-148 radar test set training.* AFHRL-TR-76-21, AD-A022 931. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, September 1975.(c)

Scott, D.L., & Joyce, R.P. *TV-2A/U tube tester training.* AFHRL-TR-76-22, AD-A022 932. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, September 1975.(d)

Scott, D.L., & Joyce, R.P. *URM-25D signal generator training.* AFHRL-TR-76-23, AD-A022 933. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, September 1975.(e)

Scott, D.L., & Joyce, R.P. *200 CD wide range oscillator training.* AFHRL-TR-76-24, AD-A022 934. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, September 1975.(f)

Scott, D.L., & Joyce, R.P. *5245L electronic counter training.* AFHRL-TR-76-25, AD-A022 939. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, September 1975.(g)

Scott, D.L., & Joyce, R.P. *Fluke 803 differential voltmeter training.* AFHRL-TR-76-26, AD-A022 956. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, September 1975.(h)

Scott, D.L., & Joyce, R.P. *HP-410B VTVM training.* AFHRL-TR-76-27, AD-A022 940. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, September 1975.(i)

Scott, D.L., & Joyce, R.P. *Key model 860 sweep generator training.* AFHRL-TR-76-28, AD-A022 957. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, September 1975.(j)

Scott, D.L., & Joyce, R.P. *SG-299 B/U signal generator training.* AFHRL-TR-76-29, AD-A022 972. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, September 1975.(k)

Scott, D.L., & Joyce, R.P. *Simpson 260 VOM training.* AFHRL-TR-76-30, AD-A022 984. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, September 1975.(l)

Shriver, E.L., & Foley, J.P., Jr. *Evaluating maintenance performance: The development and tryout of criterion referenced job task performance tests for electronic maintenance.* AFHRL-TR-74-57(II), Part I, AD-A004 845. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, September 1974.(a)

Shriver, E.L., & Foley, J.P., Jr. *Evaluating maintenance performance: The development of graphic symbolic substitutes for criterion referenced job task performance tests for electronic maintenance.* AFHRL-TR-74-57(III), AD-A005 296. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, November 1974.(b)

Shriver, E.L., & Foley, J.P., Jr. *Job performance aids for UH-1H helicopter: Controlled field tryout and evaluation.* AFHRL-TR-75-28(I), AD-B006 295L. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, June 1975. (Distribution limited to U.S. Gov't. agencies only.)

Shriver, E.L., Hayes, J.F., & Hufhand, W.R. *Evaluating maintenance performance: A video approach to symbolic testing of electronics maintenance tasks.* AFHRL-TR-74-57(IV), AD-A005 297. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, July 1974.

Shriver, E.L., Hayes, J.F., & Hufhand, W.R. *Evaluating maintenance performance: Test administrator's manual and test subject's instructions for criterion referenced job task performance tests for electronic maintenance.* AFHRL-TR-74-57(II), Part II, AD-A005 785. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, January 1975.

Vineberg, R., & Taylor, E.N. *Performance in four Army jobs at different aptitude (AFQT) levels: 3. The relationship of AFQT and job experience to job performance.* Technical Report 72-22, AD-750 630. Presidio of Monterey, CA: Human Resources Research Organization, 1972.(a)

Vineberg, R., & Taylor, E.N. *Performance in four Army jobs at different aptitude (AFQT) levels: 4. Relationships between performance criteria.* Technical Report 72-23, AD-750 604. Presidio of Monterey, CA: Human Resources Research Organization, 1972.(b)

Vineberg, R., Taylor, E.N., & Caylor, J.S. *Performance in five Army jobs by men at different aptitude (AFQT) levels: 1. Purpose and design of study.* Technical Report 70-18, AD-175 614. Presidio of Monterey, CA: Human Resources Research Organization, 1970.(a)

Vineberg, R., Taylor, E.N., & Sticht, T.G. *Performance in five Army jobs by men at different aptitude (AFQT) levels: 2. Development and description of instruments.* Technical Report 70-20, AD-720 216. Presidio of Monterey, CA: Human Resources Research Organization, 1970.(b)

Wallace, S.R. Criteria for what? *American Psychologist,* June 1965.(a)

Wallace, S.R. The relationship of psychological evaluation to needs of the Department of Defense. *Proceedings of 7th Annual Military Testing Association Conference.* AD-681 096. San Antonio, TX: October 1965, 1–10.(b)

Williams, W.L., Jr., & Whitmore, P.G., Jr. *The development and use of a performance test as a basis for comparing technicians with and without field experience.* The NIKE AJAX AFC Maintenance Technician. Technical Report 52, AD-212 663. Washington, DC: Human Resources Research Office, The George Washington University, January 1959.

BIBLIOGRAPHY

Foley, J.P., Jr. Factors to consider in developing new test and evaluation techniques. *Proceedings of the Human Factors Testing Conference*, 1–2 October 1968. Snyder, M.T. (Chm.), Kincaid, J.P., & Potempa, K.W. (Ed.), AFHRL-TR-69-6, AD-866 485. Wright-Patterson AFB, OH: Training Research Division, Air Force Human Resources Laboratory, October 1969.

Foley, J.P., Jr. *Description and results of the Air Force research and development program for the improvement of maintenance efficiency.* AFHRL-TR-72-72. AD-771 000. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, November 1973.

Harris, D., & Mackie, R.R. *Factors in influencing the use of practical performance tests in the Navy.* Navy Technical Report No. 703-1, AD-285 842. Washington, DC: Office of Naval Research, 1962.

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